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THE COMPOSITION OF THE HUMAN LENS IN HEALTH AND IN CATARACT,

AND ITS BEARING UPON OPERATIONS FOR THE LATTER.

BY

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In April, 1887, my attention was directed to the subject of the composition of the cataractous lens as compared with the healthy lens, in consequence of the question then being re-discussed as to the propriety of extraction of immature cataracts.

I was disappointed to find, on referring to the classical authorities upon the subject, how meagre was the material from which conclusions had been arrived at, and how impossible it was to equate the analyses of various observers, made at different times, in different ways, often of lenses from different animals, and with very diverse degrees of caution in eliminating numerous sources of error; and in consequence how valueless and often contradictory were the data which presumed to guide our practice in this field of ophthalmology.

I therefore determined to set to work, in such hours of leisure as I could spare from hospital and private practice, to analyse a series of healthy and cataractous lenses of different ages, all from the human subject. It is needless to say it was no easy task to obtain the material required sufficiently fresh and sufficiently intact to secure a reliable basis of comparison. Opportunities of

his kind do not present themselves every day; my researches have thus perforce been extended over a couple of years. In so far as their number is small, the results must be held to be contributory and suggestive rather than conclusive and final. I have, however, secured complete uniformity in the analyses by conducting every one of them myself, in my own laboratory, with the same apparatus and the same chemical balance in each and every case; moreover, I started and continued the observations without any preconceived ideas upon the subject, and the scattered data which have been in no way selected, have been collected, arranged and tabulated only within the last few weeks, so that I can claim that if the facts permit of any generalisation, such is the result of no *à priori* bias, but the legitimate outcome of a laborious *à posteriori* induction.

In the first place, I have dealt exclusively with human lenses; moreover, I at once discarded post-mortem material, having regard to the speedy decomposition of ocular tissues and the varying length of time which must of necessity elapse between death and the required analysis.

Cataractous lenses, the result of extraction, are of course relatively plentiful in a large clinique, but discrimination is required as to those which are available for the purpose in hand.

Those extracted in the capsule are naturally the most likely to be in perfect integrity, and when such were to be had I employed them, first removing the capsule; but these are few and far between, and consequently resort was had to cases where the cataract was ripe or very nearly so, and when the lens was delivered entire, without leaving soft cortical matter behind.*

I have analysed ten such in all, chiefly from my own operations at the North-west London and Temperance Hospitals and one or two private cases.

* There may be a possible source of error here, inasmuch as what *appears* to be a complete extraction of a cataract may leave minute portions of the cortex, and thus lessen the total weight. I do not think, however, that such error can be large, and it is to the relative rather than the absolute weights I refer, and still more to the ratio of water and solids, which would be practically unaffected by such objection.

Clear human lenses from fresh eyes are much more difficult to procure; I have secured six in all—five from cases of injury in which the eye was irretrievably damaged but without implication of the lens, and one from a case of intra-ocular tumour in which the whole anterior half of the eye was free from disease.

In some previous researches, notably those of Deutschmann, the lenses were conveyed long distances in the interval between extraction and analysis, as, for instance, from Wiesbaden and Breslau to Göttingen, and no mention is made of the mode of their preservation and protection during transportation.

In my observations the lens was, in every case, either placed in a corked, dry, glass test-tube, or sealed up in gutta-percha tissue, and was in most cases on the water-bath in my laboratory within an hour of its removal from the eye.

The data which I ascertained in each case were—

1. The weight of the lens.
2. The amount of total solids.
3. The amount of water.
4. The amount of ash.

As my object was to obtain these in relationship with age, I was unable to proceed further, *e.g.*, in the estimation of globulin, lecithin, fat, cholesterin, and soluble and insoluble salts, as the amount of material in a single lens for such purposes is inadequate for reliable result.

The mode of procedure I adopted was as follows: The lens, minus its capsule, was placed in a cleaned, dried, previously weighed platinum dish; it was reduced to fine fragments by a couple of needles, care being taken to remove no lens matter with them; the whole was then again weighed. The object of the trituration was to increase facility for the escape of water.

The platinum dish was at once transferred to the water-bath, kept at 100° C.; after forty-five minutes it was again weighed, and this was repeated at intervals of ten or fifteen minutes until a constant weight was secured. The weight of the dish being deducted, the amount of total solids was obtained; this, taken from the weight of the whole lens, of course gave the amount of the water. The residue was then incinerated in the Bunsen flame until no

blackness remained, and after cooling was again weighed. The bulk of this saline residue was NaCl.

Having explained the method, I proceed to my results. These are given in the accompanying table. The first column shows the

TABLE OF COMPARATIVE ANALYSES OF SIX CLEAR HUMAN LENSES AND TEN HUMAN CATARACTOUS LENSES.

	Age.	Weight.	Water.	Solids.	Ash.	Per Cent.		
						Water.	Solids.	Ash.
Clear.	10	·163	·113	·050	·001	69	31	·6
	26	·215	·153	·062	·002	71	29	·9
	27	·188	·136	·052	·001	72	28	·5
	28	·1915	·132	·0595	·002	69	31	1·0
	40	·2175	·1575	·060	·001	73	27	·4
	64	·247	·176	·071	·001	71	29	·4
		·2036	**·1446**	**·059**	**·0013**	**71**	**29**	**·6**
Cataracts.	46	·13625	·10150	·03475	·00175	74·5	25·5	1·3
	47	·116	·081	·035	·002	70	30	1·7
	53	·1351	·0926	·0425	·001	68·5	31·5	·7
	59	·0830	·042	·041	·002	52	48	5·0
	60	·128	·095	·033	·0015	74	26	1·2
	61	·100	·070	·030	·001	67	33	1·0
	63	·110	·0725	·0375	·002	66	34	1·8
	64	·101	·0575	·0435	·001	74	26	1·2
	77	·110	·071	·039	·001	64·5	35·5	·9
	87	·110	·0445	·0655	·001	40·5	59·5	·9
		·113	**·073**	**·040**	**·0014**	**65**	**35**	**1·57**

ages, the second the weights of the lenses, the third the amount of contained water, the fourth the total solids, the fifth the ash; the sixth, seventh, and eighth give the percentage of the water, solids, and ash to the total weight. The six clear lenses come first, and below them the cataracts. The figures in thicker type are the averages. As to the ages, I have to regret that circumstances over which I had no control have constituted the clear lenses a younger series than the cataracts. The average of the former is 32·5 (the extremes 10 and 64), of the latter 61·7 (the extremes 46 and 87). This has been unavoidable, having regard to the source of the material, but I am not aware that on consideration of the tables, along with such other knowledge as we possess, it will materially invalidate the result; or at any rate that the data we have will not afford sufficient suggestion as to the data we have not to permit of just allowance being made for the latter, and fallacies being thereby avoided.

Directing our attention in the first place to the healthy lenses, as regards weight there appears to be a regular increase with age (with one single exception, however, the lens aged twenty-six), from ·163 gramme at ten to ·247 gramme at sixty-four.

I need not dwell at any length on this subject, which has been so fully elaborated by at least one careful and able observer.

Priestley Smith's valuable paper on the growth of the lens in vol. iii. of the Ophthalmological Society's Transactions was based upon observations made upon 156 lenses removed after death, as to weight, volume, and equatorial diameter, while the specific gravity he calculated from the weight and volume.

He found the weight of the lens between twenty and twenty-nine to average 174 milligrammes; between sixty and sixty-nine, 240 milligrammes. The average volume he found to increase in nearly the same proportion as the weight, from 163 cub. mm. to 225 cub. mm., or an annual increase of about 1·5 cub. mm.

My few results, obtained from perfectly fresh lenses, are in almost complete accord with Priestley Smith's figures, derived from post-mortem specimens; and I may here add that I had not read Priestley Smith's paper before I tabulated my figures.

The average weight of the six clear lenses I examined was about two decigrammes.

As to the amount of water, I find that this remains in the clear lenses remarkably constant, about 70 per cent. Its absolute amount increases nearly in the same ratio as the whole lens; it is much the same in the child of ten, the young adult, and the man of sixty. Kuhne, whom most of the books copy, gives 60 per cent. of water in the healthy lens, Laptschinksy from four analyses of the lens of oxen made it 63·51, Schneyder found it 63·267 in a boy aged five months; Wecker and Landolt say 60. Jacobsen comes nearer to my figure; he gives 70·8.

The amount of the total solids, it follows from what I have said, also remains tolerably constant throughout life, viz., about 30 per cent., the extremes being 27·12 and 31·07, a range of variation of only 4 per cent.

This result differs from Deutschmann, who found the total solids increase with age, not only absolutely but relatively to the water, from 29·2 per cent. to 35·4 per cent., an increase of 6 per cent., but as I said before, his observations were vitiated by the transport of the lenses.

This absence of the diminution of the amount of water and increase of solids in the lens with age may appear to be contrary to *à priori* reasonings based on general impressions and from the cuticular homologies of the lens.

Becker, in Graefe and Saemisch's handbook, says that "the young lens fibres are thicker, softer, richer in water, freer from colour; the older they grow the more they give up their water and become flat, closely compacted, and amber coloured." Again, he says in his monograph that Deutschmann found what had previously been believed, *i.e.*, that the solids increased with age; apparently these are the grounds for the statements, and they, for the reasons which Becker himself points out, are not of an unassailable character.

Donders, again, hints at an increase of density of the lens with age in dealing with acquired hypermetropia.

On the other hand, my conclusion is strikingly corroborated by the calculated specific gravities of lenses of different ages which Priestley Smith thus tabulates :—

Age.	Spec. Grav.
20-29	1,067
30-39	1,085
40-49	1,085
60-69	1,067

and he draws the conclusion that the specific gravity of the lens is, on the average, nearly the same at different periods of adult life; in fact *the increase of its weight is due not to an increase of density, but to an augmentation of size.*

Indeed, upon reflection, the fictitious sclerosis of the lens fibres, which has been alleged, in so far as that term suggests dehydration, is in no sense corollary to its derivation from cuticular epiblast or its homologous relationship with the epidermis. Because the latter exposed to air and pressure tends to cornification and dehydration from its surface, that, I submit, is no reason why the lens excluded from air, nay, bathed with fluid, should exhibit a similar change at its nucleus, which is required to make this fallacious analogy complete. The growth and nutrition of the lens are without parallel in any other tissue of the body.

The ash of the healthy lens is very constant, and weighs about 1 milligramme, less than 1 per cent. of the whole lens, and shows no variation correspondent with age.

Turning now to the series of recent cataractous lenses, ten in number, removed from persons aged from forty-six to eighty-seven (averaging sixty-one), I find as regards the absolute weight that in not one single instance did this reach, nay, did not approach, the weight of the lightest of the clear lenses. Their average weight was ·113 gramme, against ·203 in the former series. Moreover, the heaviest was the youngest of the series, and the tendency was rather to diminish with age, the reverse of what obtained in the clear lenses. This result is the more striking when we remember that all the evidence at hand goes to show that the healthy lens continually increases in weight with advancing years, and in all probability the contrast would have been still more striking if the series of healthy lenses were extended to later ages.

Here, again, my results yield unsolicited corroboration of Priestley Smith's observations. He says, "The lenses in which cataract was beginning were, as a rule, smaller than transparent lenses of the same age."

In the tables which he appends to his paper I can find only two weights of completely cataractous lenses. One of these, aged sixty-nine, weighed ·184 gramme; the other, aged seventy-six, weighed ·175 gramme; figures much below the average weight of healthy lenses of those ages as given in his tables.

Now as to the composition of cataract in respect of water and solids. I find both to be absolutely less than in healthy lenses, but not in the same degree. The average amount of water in the clear lenses weighed ·1446 gramme, that in the cataract ·073 gramme; the average amount of total solids was in the clear ·059, in the cataracts ·040. The highest figure for the water in any cataract was ·1015, there being no regular variation with age; on the other hand, the lowest figure for the water in the clear lenses was ·113.

The highest for solids in the cataracts was ·065, in the oldest of the series, aged eighty-seven, which was the only one which exceeded the lowest figure for the solids among the clear lenses, the next highest being ·0435, the lowest of the clear being ·050.

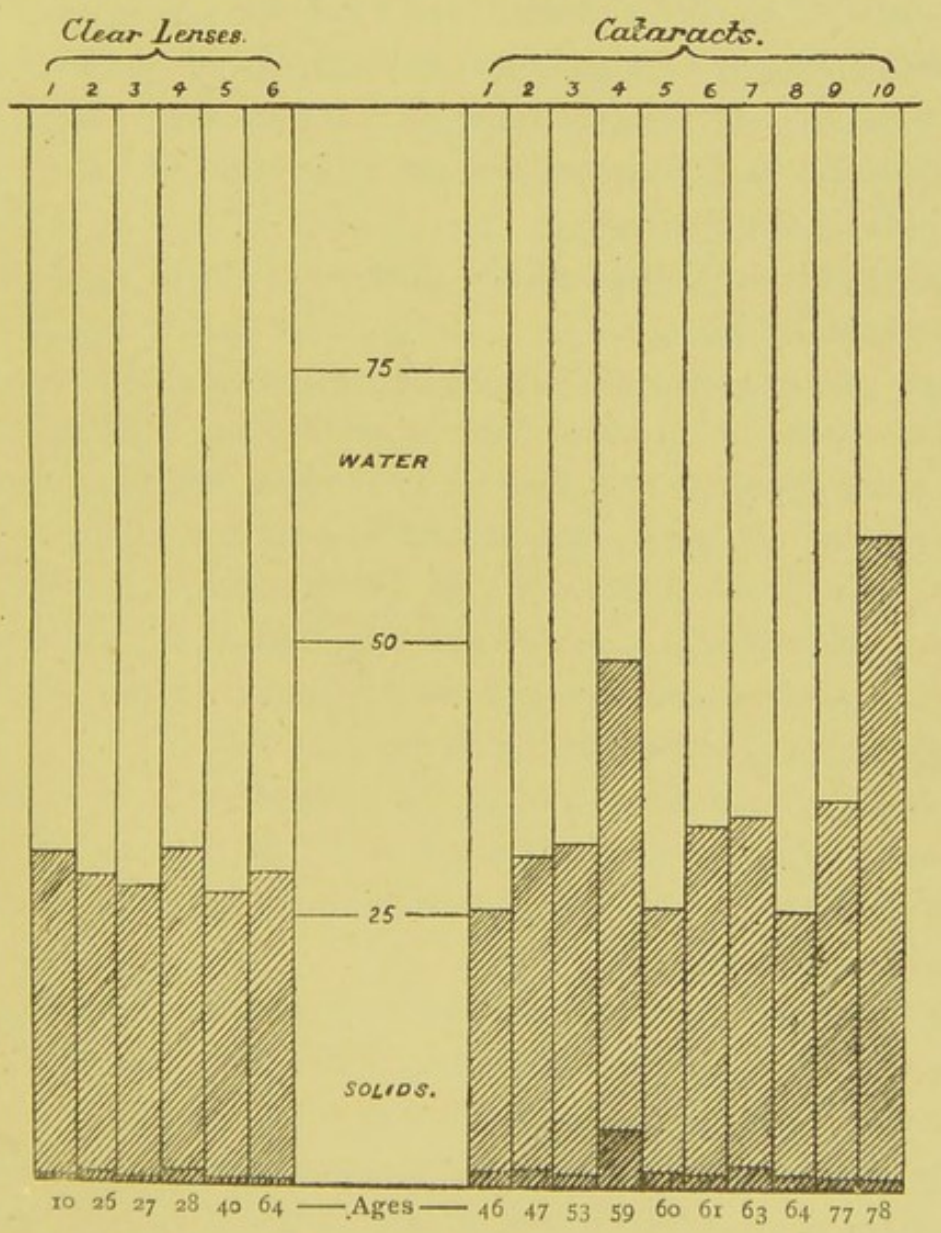
As to the relative proportions of water and solids in the cataracts, this showed a much greater range of variation than in the case of the clear lenses. In the latter case the average proportions were 71 water to 29 solids, while in the cataracts the average proportions are 65 water to 35 solids, an excess of 6 per cent. of solids; whereas the range is at least 30 per cent., viz., in the case of the solids from 25·5 in the youngest to 59·5 in the oldest.

As with the clear lenses, so with the cataracts, it would appear that individual peculiarities rather than any age changes determine the ratio of water and solids; a lens, whether clear or opaque, does not necessarily become denser as it becomes old, while it is nevertheless true that the law of continuous lens growth which obtains in health does not hold, indeed shows a tendency to arrest or inversion, when the cataractous change appears.

The ash of cataracts is nearly the same absolutely as in clear lenses; this, taken in connection with their lighter weight, shows

TABLE showing Percentage Composition as to *Water*, *Solids*, and *Ash* of 6 *Clear* and 10 *Cataractous* Human Lenses.

(*Water white; Solids shaded; Ash a darker shade.*)



on an average a relative excess of ash amounting to about 50 per cent.

Otto Becker, from an analysis of four senile cataracts extracted within their capsules, and one incipient cataract, found 76·23 per

cent. to 69·06 per cent. of water; in the incipient cataract the solids were the least.

Jacobsen, from analyses of cataract not intra-capsularly extracted, found the water to be 63·45 per cent. to 73·6 per cent.

Becker seems to incline to the opinion that in ripe or ripening, but not shrunken cataracts the water is increased in amount.

In order to eliminate errors based upon the smallness of the material employed, I secured four cataracts, all nearly intact and quite fresh, from persons aged sixty, sixty-seven, seventy-three, and seventy-seven, and estimated the water, solids, and ash in the combined lens matter.

The results were 62·14 per cent. of water, 37·86 of solids, and ·83 per cent. of ash.

None of these were what could be termed *cataracta reducta;* and the conclusion to which I am irresistibly led from this and every other observation is that while allowing individual exceptions, cataractous lenses as a general rule contain relatively less water and more solids and ash than non-cataractous lenses, and that this dehydration, associated with opacification, is in no sense a change dependent upon age, and has no parallel in the ordinary changes which age brings with it in the clear lens.

Such slight upward tendency of the ratio of solids to water in older cataracts as may be detected in my diagram and figures would appear to be referable, then, rather to the age of the cataract than to that of the lens.

The cataractous process is not an exaggerated senile change, but due to disturbed nutrition of quite another nature, in so far as chemical and not morphological changes are concerned.

Turning now to the question of the practical bearing of these conclusions upon operations for cataract, I would remark that if the argument be advanced that early extraction should be adopted in cases of immature cataract in persons past middle life, because the cataract in such cases is likely to be hard (*i.e.*, rich in solids), on account of age apart from the cataractous change, then my analyses afford no ground for any such generalisation. A wide diversity obtains in the solidity of cataractous lenses, a range of

20 or 30 per cent., a diversity which has no correspondence in the case of non-cataractous lenses; the cataractous change is not one exclusively of loss of water; the cataractous lens is a light lens—a small lens—one in which the normal continuous evolution has been checked or inverted; there is absolutely less water, less solid, but not less ash than in health, but the ratio of the solid to the water, while generally increased, exhibits wide variability in individual cases.

In deciding the question of operation on immature cataracts, then, I submit we must be guided by the circumstances of the individual case, especially the general and local conditions of nutrition, particularly diathetic and vascular conditions.

A cataract is not likely to be more solid (*i.e.*, containing less water) because the lens in which the change has occurred is an old one, and any treatment based on such supposition is fallacious and unsound.

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